

WHAT IS CLAIMED IS:

1 1. An objective comprising a plurality of lenses,
2 wherein at least two lenses consist of fluoride crystal
3 material with a cubic lattice structure and wherein said
4 fluoride crystal lenses are (111)-lenses each having a lens
5 axis oriented approximately perpendicular to the {111}-
6 planes or to crystallographic planes that are equivalent to
7 the {111}-planes of the fluoride crystal, wherein an image
8 point in an image plane is formed at a convergence of a
9 bundle of light rays each of which has an azimuth angle α_R ,
10 an aperture angle θ_R and an optical path difference ΔOPL for
11 two mutually orthogonal states of linear polarization,
12 wherein said (111)-lenses are arranged with a rotation
13 relative to each other about the lens axes in such a manner
14 that a distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path
15 differences as a function of the azimuth angle α_R and the
16 aperture angle θ_R has significantly reduced values of ΔOPL
17 in comparison to an arrangement where said (111)-lenses are
18 not arranged with said rotation relative to each other.

1 2. The objective of claim 1, wherein the values of
2 the distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path differences

3 as a function of the azimuth angle α_R at a fixed aperture
4 angle θ_0 vary by less than 20%, said percentage being
5 relative to a maximum value of the distribution $\Delta OPL(\alpha_R, \theta_R)$
6 of the optical path differences.

1 3. The objective of claim 1, wherein said (111)-
2 lenses are arranged with an angle of rotation γ relative to
3 each other about the lens axes, wherein a number n of
4 (111)-lenses form a group and the angle of rotation γ
5 between two of the (111)-lenses of said group conforms to
6 the equation $\gamma = \frac{120^\circ}{n} + m \cdot 120^\circ \pm 8^\circ$ with m representing an
7 integer.

1 4. The objective of claim 3, wherein an outermost
2 aperture ray of the bundle of light rays has a lens-
3 specific aperture angle θ_L within each of the (111)-lenses,
4 and wherein said lens-specific aperture angle θ_L varies for
5 the (111)-lenses of said group by no more than 30%, said
6 percentage being relative to a maximum aperture angle among
7 all (111)-lenses of said group.

1 5. The objective of claim 3, wherein an outermost

2 aperture ray of the bundle of light rays travels a lens-
3 specific path length RL_L within each of the (111)-lenses,
4 and wherein said lens-specific path length RL_L varies for
5 the (111)-lenses of said group by no more than 30%, said
6 percentage being relative to a maximum path length among
7 all (111)-lenses of said group.

1 6. The objective of claim 3, wherein an outermost
2 aperture ray of the bundle of light rays is subject to a
3 lens-specific optical path difference ΔOPL within each of
4 the (111)-lenses which is determined for non-rotated (111)-
5 lenses, and wherein said lens-specific optical path
6 difference ΔOPL varies for the (111)-lenses of said group
7 by no more than 30%, said percentage being relative to a
8 maximum optical path difference among all (111)-lenses of
7 said group.

1 7. The objective of claim 3, comprising at least
2 two groups of (111)-lenses, wherein the (111)-lenses within
3 each of the at least two groups are rotated relative to
4 each other.

1 8. A method of manufacturing objectives that

2 comprise at least two fluoride crystal lenses, wherein the
3 term lenses means lenses as well as lens parts, wherein
4 said fluoride crystal lenses are (111)-lenses each having a
5 lens axis oriented approximately perpendicular to the
6 {111}-planes or to crystallographic planes that are
7 equivalent to the {111}-planes of the fluoride crystal, the
8 method comprising the steps of:
9 a) determining a distribution function $\Delta\text{OPL}(\alpha_R, \theta_R)$ of
10 optical path differences ΔOPL for light rays belonging
11 to a bundle of rays traveling through the objective,
12 wherein α_R represents an azimuth angle, θ_R represents an
13 aperture angle, and ΔOPL represents an optical path
14 difference of each light ray for two mutually
15 orthogonal states of linear polarization in an image
16 plane of the objective, and
17 b) arranging the (111)-lenses in rotated positions
18 relative to each other about the lens axes in such a
19 manner that a remaining distribution function $\Delta\text{OPL}(\alpha_R,$
20 $\theta_R)$ is significantly reduced in magnitude compared to an
21 arrangement where the (111)-lenses are not arranged in
22 said rotated positions.

1 9. An objective comprising a plurality of lenses,

2 wherein at least two lenses consist of fluoride crystal
3 material with a cubic lattice structure and wherein said
4 fluoride crystal lenses are (100)-lenses each having a lens
5 axis oriented approximately perpendicular to the {100}-
6 planes or to crystallographic planes that are equivalent to
7 the {100}-planes of the fluoride crystal, wherein an image
8 point in an image plane is formed at a convergence of a
9 bundle of light rays each of which has an azimuth angle α_R ,
10 an aperture angle θ_R and an optical path difference ΔOPL for
11 two mutually orthogonal states of linear polarization,
12 wherein said (100)-lenses are arranged with a rotation
13 relative to each other about the lens axes in such a manner
14 that a distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path
15 differences as a function of the azimuth angle α_R and the
16 aperture angle θ_R has significantly reduced values of ΔOPL
17 in comparison to an arrangement where said (100)-lenses are
18 not arranged with said rotation relative to each other.

1 10. The objective of claim 9, wherein the values
2 of the distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path
3 differences as a function of the azimuth angle α_R at a fixed
4 aperture angle θ_0 vary by less than 20%, said percentage

5 being relative to a maximum values of the distribution
6 $\Delta OPL(\alpha_R, \theta_R)$ of the optical path differences..

1 11. The objective of claim 9, wherein said (100)-
2 lenses are arranged with an angle of rotation γ relative to
3 each other about the lens axes, wherein a number n of
4 (100)-lenses form a group and the angle of rotation γ
5 between two of the (100)-lenses of said group conforms to
6 the equation $\gamma = \frac{90^\circ}{n} + m \cdot 90^\circ \pm 5^\circ$ with m representing an integer.

1 12. The objective of claim 11, wherein an
2 outermost aperture ray of the bundle of light rays has a
3 lens-specific aperture angle θ_L within each of the (100)-
4 lenses, and wherein said lens-specific aperture angle θ_L
5 varies for the (100)-lenses of said group by no more than
6 30%, said percentage being relative to a maximum aperture
7 angle among all (100)-lenses of said group.

1 13. The objective of claim 11, wherein an
2 outermost aperture ray of the bundle of light rays travels
3 a lens-specific path length RL_L within each of the (100)-
4 lenses, and wherein said lens-specific path length RL_L

5 varies for the (100)-lenses of said group by no more than
6 30%, said percentage being relative to a maximum path
7 length among all (100)-lenses of said group.

1 14. The objective of claim 11, wherein an
2 outermost aperture ray of the bundle of light rays is
3 subject to a lens-specific optical path difference ΔOPL
4 within each of the (100)-lenses which is determined for
5 non-rotated (100)-lenses, and wherein said lens-specific
6 optical path difference ΔOPL varies for the (100)-lenses of
7 said group by no more than 30%, said percentage being
8 relative to a maximum optical path difference among all
9 (100)-lenses of said group.

1 15. The objective of claim 11, comprising at least
2 two groups of (100)-lenses, wherein the (100)-lenses within
3 each of the at least two groups are rotated relative to
4 each other.

1 16. A method of manufacturing objectives that
2 comprise at least two fluoride crystal lenses, wherein the
3 term lenses means lenses as well as lens parts, wherein
4 said fluoride crystal lenses are (100)-lenses each having a

5 lens axis oriented approximately perpendicular to the
6 {100}-planes or to crystallographic planes that are
7 equivalent to the {100}-planes of the fluoride crystal, the
8 method comprising the steps of:
9 a) determining a distribution function $\Delta\text{OPL}(\alpha_R, \theta_R)$ of
10 optical path differences ΔOPL for light rays belonging
11 to a bundle of rays traveling through the objective,
12 wherein α_R represents an azimuth angle, θ_R represents an
13 aperture angle, and ΔOPL represents an optical path
14 difference of each light ray for two mutually
15 orthogonal states of linear polarization in an image
16 plane of the objective, and
17 b) arranging the (100)-lenses in rotated positions
18 relative to each other about the lens axes in such a
19 manner that a remaining distribution function $\Delta\text{OPL}(\alpha_R,$
20 $\theta_R)$ is significantly reduced in magnitude compared to an
21 arrangement where the (100)-lenses are not arranged in
22 said rotated positions.

1 17. A method of manufacturing objectives that
2 comprises a plurality of lenses, wherein at least two
3 lenses of at least one first group consist of fluoride
4 crystal material with a cubic lattice structure and wherein

5 said fluoride crystal lenses are (111)-lenses each having a
6 lens axis oriented approximately perpendicular to the
7 {111}-planes or to crystallographic planes that are
8 equivalent to the {111}-planes of the fluoride crystal,

9 and wherein at least two lenses of at least one
10 second group consist of fluoride crystal material with a
11 cubic lattice structure and wherein said fluoride crystal
12 lenses are (100)-lenses each having a lens axis oriented
13 approximately perpendicular to the {100}-planes or to
14 crystallographic planes that are equivalent to the {100}-
15 planes of the fluoride crystal, the method comprising the
16 steps of:

- 17 a) determining a distribution function $\Delta\text{OPL}(\alpha_R, \theta_R)$ of
18 optical path differences ΔOPL for light rays belonging
19 to a bundle of rays traveling through the objective,
20 wherein α_R represents an azimuth angle, θ_R represents an
21 aperture angle, and ΔOPL represents an optical path
22 difference of each light ray for two mutually
23 orthogonal states of linear polarization in an image
24 plane of the objective, and
- 25 b) arranging said (111)-lenses of said first group and
26 said (100)-lenses of said second group with a rotation
27 relative to each other about the lens axes in such a

28 manner that a remaining distribution function $\Delta OPL(\alpha_R,$
29 $\theta_R)$ is significantly reduced in magnitude compared to an
30 arrangement where said (111)-lenses of said first group
31 and said (100)-lenses of said second group are not
32 arranged with said rotation relative to each other.

1 18. An objective comprising at least two lenses
2 consisting of fluoride crystal material, wherein the term
3 lenses means lenses as well as lens parts, wherein said
4 lenses have lens axes oriented substantially in a principal
5 crystallographic direction, wherein an image point in an
6 image plane (O') is formed at a convergence of a bundle of
7 light rays each of which has an azimuth angle α_R , an
8 aperture angle θ_R and an optical path difference ΔOPL for
9 two mutually orthogonal states of linear polarization,
10 wherein the lenses are arranged with a rotation relative to
11 each other about the lens axes in such a manner that a
12 distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path differences as
13 a function of the azimuth angle α_R and the aperture angle
14 θ_R has significantly reduced values of ΔOPL in comparison to
15 an arrangement where said lenses are likewise oriented in
16 said principal crystallographic direction but are not
17 arranged with said rotation relative to each other.

1 19. The objective of claim 18, wherein the values
2 of the distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path
3 differences as a function of the azimuth angle α_R at a fixed
4 aperture angle θ_0 vary by less than 30% relative to a
5 maximum value of $\Delta OPL(\alpha_R, \theta_R)$.

1 20. The objective of claim 18, wherein the lens
2 axes are oriented in the crystallographic <111>-direction
3 or a principal crystallographic direction equivalent to the
4 <111>-direction.

1 21. The objective of claim 18, wherein the lens
2 axes are oriented in the crystallographic <100>-direction
3 or a principal crystallographic direction equivalent to the
4 <100>-direction.

1 22. The objective of claim 18, wherein the lens
2 axes are oriented in the crystallographic <110>-direction
3 or a principal crystallographic direction equivalent to the
4 <110>-direction.

1 23. The objective of claim 18, wherein the

2 objective conforms to at least one of the criteria that:

3 - the objective has a numerical aperture NA larger than

4 0.7 on the image side,

5 - the objective has a numerical aperture NA larger than

6 0.8 on the image side,

7 - the objective is designed to operate with wavelengths

8 shorter than 200 nanometers,

9 - the objective is designed to operate with wavelengths

10 shorter than 160 nanometers,

11 - the objective is a refractive objective,

12 - the objective is a catadioptric objective with lenses

13 and at least one mirror, and

14 - all lenses of the objective consist of calcium fluoride.

1 24. The optical element of claim 18, wherein the

2 fluoride crystal material comprises one of a calcium

3 fluoride crystal, a strontium fluoride crystal, and a

4 barium fluoride crystal.

1 25. The objective of claim 18, comprising at least

2 one first group of lenses whose lens axes are oriented in

3 the crystallographic <100>-direction or a <100>-equivalent

4 principal crystallographic direction, and further

5 comprising at least one second group of lenses whose lens
6 axes are oriented in one of a first or second different
7 crystallographic direction in relation to said first group.

1 26. The objective of claim 25, wherein said first
2 different crystallographic direction consists of the <111>-
3 direction or a <111>-equivalent principal crystallographic
4 direction, and said second different crystallographic
5 direction consists of the <110>-direction or a <110>-
6 equivalent principal crystallographic direction.

1 27. The objective of claim 26, wherein the at
2 least one first group causes a first distribution of
3 optical path differences $\Delta OPL_1(\alpha_R, \theta_R)$, the at least one
4 second group causes a second distribution of optical path
5 differences $\Delta OPL_2(\alpha_R, \theta_R)$, and the objective causes a
6 resultant distribution of optical path differences
7 $\Delta OPL(\alpha_R, \theta_R)$ representing the superposition of said first and
8 second distributions, and wherein the first distribution
9 has a first maximum value that differs by no more than 30%
10 from a second maximum value of the second distribution,
11 said percentage being relative to the larger of the first
12 and second maximum values.

1 28. The objective of claim 18, wherein each of the
2 lenses has a birefringence distribution $\Delta n(\alpha_L, \theta_L)$ whose
3 values Δn depend on aperture angles θ_L relative to the lens
4 axis and on azimuth angles α_L relative to a reference
5 direction that is perpendicular to the lens axis, wherein
6 the birefringence distribution $\Delta n(\alpha_L, \theta_L)$ has a k-fold
7 azimuthal symmetry, wherein angles of rotation γ are defined
8 between the reference directions of the individual lenses,
9 wherein a number n of lenses form a group in which the lens
10 axes are oriented in the same or equivalent
11 crystallographic directions, and wherein in said group the
12 birefringence distributions $\Delta n(\alpha_L, \theta_L)$ relative to the
13 reference directions have the same azimuthal profiles and
14 the angle of rotation γ between two of the lenses conforms
15 to the equation $\gamma = \frac{360^\circ}{k \cdot n} + m \cdot \frac{360^\circ}{k} \pm 10^\circ$ with m representing an
16 integer.

1 29. The objective of claim 28, wherein an
2 outermost aperture ray of the bundle of light rays has a
3 lens-specific aperture angle θ_L within each of the lenses,
4 and wherein said lens-specific aperture angle θ_L varies for

5 the lenses of the group by no more than 30%, said
6 percentage being relative to a maximum aperture angle among
7 all lenses of the group.

1 30. The objective of claim 28, wherein an
2 outermost aperture ray of the bundle of light rays travels
3 a lens-specific path length RL_L within each of the lenses,
4 and wherein said lens-specific path length RL_L varies for
5 the lenses of the group by no more than 30%, said
6 percentage being relative to a maximum path length among
7 all lenses of the group.

1 31. The objective of claim 28, wherein an
2 outermost aperture ray of the bundle of light rays is
3 subject to a lens-specific optical path difference ΔOPL
4 within each of the lenses which is determined for non-
5 rotated lenses, and wherein said lens-specific optical path
6 difference ΔOPL varies for the lenses of the group by no
7 more than 30%, said percentage being relative to a maximum
8 optical path difference among all lenses of the group.

1 32. The objective of claim 28, wherein the group
2 comprises two to four lenses.

1 33. The objective of claim 32, wherein the lenses
2 of the group are arranged next to each other.

1 34. The objective of claim 33, wherein the lenses
2 of the group comprise lens parts joined together by
3 wringing.

1 35. The objective of claim 28, comprising at least
2 two groups of lenses, wherein the lenses within each of the
3 at least two groups are rotated relative to each other.

1 36. The objective of claim 28, wherein the lens
2 axes are oriented in the crystallographic <111>-direction
3 or a principal crystallographic direction equivalent to the
4 <111>-direction, and wherein the birefringence distribution
5 $\Delta n(\alpha_L, \theta_L)$ of the lenses has a threefold azimuthal symmetry.

1 37. The objective of claim 28, wherein the lens
2 axes are oriented in the crystallographic <100>-direction
3 or a principal crystallographic direction equivalent to the
4 <100>-direction, and wherein the birefringence distribution
5 $\Delta n(\alpha_L, \theta_L)$ of the lenses has a fourfold azimuthal symmetry.

1 38. The objective of claim 28, wherein the lens
2 axes are oriented in the crystallographic <110>-direction
3 or a principal crystallographic direction equivalent to the
4 <110>-direction, and wherein the birefringence distribution
5 $\Delta n(\alpha_L, \theta_L)$ of the lenses has a twofold azimuthal symmetry.

1 39. The objective of claim 28, wherein the
2 objective conforms to at least one of the criteria that:
3 - the objective has a numerical aperture NA larger than
4 0.7 on the image side,
5 - the objective has a numerical aperture NA larger than
6 0.8 on the image side,
7 - the objective is designed to operate with wavelengths
8 shorter than 200 nanometers,
9 - the objective is designed to operate with wavelengths
10 shorter than 160 nanometers,
11 - the objective is a refractive objective,
12 - the objective is a catadioptric objective with lenses
13 and at least one mirror, and
14 - all lenses of the objective consist of calcium fluoride.

1 40. The objective of claim 28, comprising at least

2 one first group of lenses whose lens axes are oriented in
3 the crystallographic <100>-direction or a <100>-equivalent
4 principal crystallographic direction, and further
5 comprising at least one second group of lenses whose lens
6 axes are oriented in one of a first or second different
7 crystallographic direction in relation to said first group.

1 41. The objective of claim 40, wherein said first
2 different crystallographic direction consists of the <111>-
3 direction or a <111>-equivalent principal crystallographic
4 direction, and said second different crystallographic
5 direction consists of the <110>-direction or a <110>-
6 equivalent principal crystallographic direction.

1 42. The objective of claim 41, wherein the at
2 least one first group causes a first distribution of
3 optical path differences $\Delta OPL_1(\alpha_R, \theta_R)$, the at least one
4 second group causes a second distribution of optical path
5 differences $\Delta OPL_2(\alpha_R, \theta_R)$, and the objective causes a
6 resultant distribution of optical path differences
7 $\Delta OPL(\alpha_R, \theta_R)$ representing the superposition of said first and
8 second distributions, and wherein the first distribution
9 has a first maximum value that differs by no more than 30%

10 from a second maximum value of the second distribution,
11 said percentage being relative to the larger of the first
12 and second maximum values.

1 43. The objective of claim 18, wherein each of the
2 lenses has a birefringence distribution $\Delta n(\alpha_L, \theta_L)$ whose
3 values Δn depend on aperture angles θ_L relative to the lens
4 axis and on azimuth angles α_L relative to a reference
5 direction that is perpendicular to the lens axis, wherein
6 the birefringence distribution $\Delta n(\alpha_L, \theta_L)$ has a k-fold
7 azimuthal symmetry, wherein angles of rotation γ are defined
8 between the reference directions of the individual lenses,
9 wherein a number n of subgroups of lenses form a group in
10 which the lens axes are oriented in the same or equivalent
11 crystallographic directions, and wherein in said group the
12 birefringence distributions $\Delta n(\alpha_L, \theta_L)$ relative to the
13 reference directions have the same azimuthal profiles,
14 wherein each of the n subgroups comprises at least one
15 lens, wherein the angle of rotation γ between any two of the
16 lenses within one of the subgroups conforms to the equation
17 $\gamma = 1 \cdot \frac{360^\circ}{k} \pm 10^\circ$ and the angle of rotation γ between two lenses
18 from different subgroups conforms to the equation

19 $\gamma = \frac{360^\circ}{k \cdot n} + m \cdot \frac{360^\circ}{k} \pm 10^\circ$ with l and m representing integer
20 numbers.

1 44. The objective of claim 43, comprising at least
2 two groups of lenses, wherein the lenses within each of the
3 at least two groups are rotated relative to each other.

1 45. The objective of claim 43, wherein the lens
2 axes are oriented in the crystallographic <111>-direction
3 or a principal crystallographic direction equivalent to the
4 <111>-direction, and wherein the birefringence distribution
5 $\Delta n(\alpha_L, \theta_L)$ of the lenses has a threefold azimuthal symmetry.

1 46. The objective of claim 43, wherein the lens
2 axes are oriented in the crystallographic <100>-direction
3 or a principal crystallographic direction equivalent to the
4 <100>-direction, and wherein the birefringence distribution
5 $\Delta n(\alpha_L, \theta_L)$ of the lenses has a fourfold azimuthal symmetry.

1 47. The objective of claim 43, wherein the lens
2 axes are oriented in the crystallographic <110>-direction
3 or a principal crystallographic direction equivalent to the

4 <110>-direction, and wherein the birefringence distribution
5 $\Delta n(\alpha_L, \theta_L)$ of the lenses has a twofold azimuthal symmetry.

1 48. The objective of claim 43, wherein the
2 objective conforms to at least one of the criteria that:
3 - the objective has a numerical aperture NA larger than
4 0.7 on the image side,
5 - the objective has a numerical aperture NA larger than
6 0.8 on the image side,
7 - the objective is designed to operate with wavelengths
8 shorter than 200 nanometers,
9 - the objective is designed to operate with wavelengths
10 shorter than 160 nanometers,
11 - the objective is a refractive objective,
12 - the objective is a catadioptric objective with lenses
13 and at least one mirror, and
14 - all lenses of the objective consist of calcium fluoride.

1 49. The objective of claim 43, comprising at least
2 one first group of lenses whose lens axes are oriented in
3 the crystallographic <100>-direction or a <100>-equivalent
4 principal crystallographic direction, and further
5 comprising at least one second group of lenses whose lens

6 axes are oriented in one of a first or second different
7 crystallographic direction in relation to said first group.

1 50. The objective of claim 49, wherein said first
2 different crystallographic direction consists of the <111>-
3 direction or a <111>-equivalent principal crystallographic
4 direction, and said second different crystallographic
5 direction consists of the <110>-direction or a <110>-
6 equivalent principal crystallographic direction.

1 51. The objective of claim 50, wherein the at
2 least one first group causes a first distribution of
3 optical path differences $\Delta OPL_1(\alpha_R, \theta_R)$, the at least one
4 second group causes a second distribution of optical path
5 differences $\Delta OPL_2(\alpha_R, \theta_R)$, and the objective causes a
6 resultant distribution of optical path differences
7 $\Delta OPL(\alpha_R, \theta_R)$ representing the superposition of said first and
8 second distributions, and wherein the first distribution
9 has a first maximum value that differs by no more than 30%
10 from a second maximum value of the second distribution,
11 said percentage being relative to the larger of the first
12 and second maximum values.

1 52. A microlithography projection system,
2 comprising an illumination system and further comprising
3 the objective of claim 18, wherein the objective projects
4 an image of a mask carrying a structure onto a light-
5 sensitive substrate.

1 53. A method of manufacturing semiconductor
2 components comprising a step in which the microlithography
3 projection system of claim 52 is used.

1 54. A method of manufacturing objectives that
2 comprise at least two fluoride crystal lenses, wherein the
3 term lenses means lenses as well as lens parts, wherein
4 said lenses have lens axes and each of said lens axes is
5 oriented substantially in a principal crystallographic
6 direction, the method comprising the steps of:
7 a) determining a distribution function $\Delta OPL(\alpha_R, \theta_R)$ of
8 optical path differences ΔOPL for light rays belonging
9 to a bundle of rays traveling through the objective,
10 wherein α_R represents an azimuth angle, θ_R represents an
11 aperture angle, and ΔOPL represents an optical path
12 difference of each light ray for two mutually
13 orthogonal states of linear polarization in an image

14 plane of the objective, and
15 b) arranging the lenses in rotated positions relative to
16 each other about the lens axes in such a manner that a
17 remaining distribution function $\Delta OPL(\alpha_R, \theta_R)$ is
18 significantly reduced in magnitude compared to an
19 arrangement where each lens is oriented likewise in
20 said principal crystallographic direction but where the
21 lenses are not arranged in said rotated positions.

1 55. The method of claim 54, wherein the objective
2 comprises at least one first group of lenses whose lens
3 axes are oriented in the crystallographic <100>-direction
4 or a <100>-equivalent principal crystallographic direction,
5 and at least one second group of lenses whose lens axes are
6 oriented in the crystallographic <111>-direction or a
7 <111>-equivalent principal crystallographic direction.

1 56. The method of claim 54, wherein the objective
2 comprises at least one first group of lenses whose lens
3 axes are oriented in the crystallographic <100>-direction
4 or a <100>-equivalent principal crystallographic direction,
5 and at least one second group of lenses whose lens axes are
6 oriented in the crystallographic <110>-direction or a

7 <110>-equivalent principal crystallographic direction.

1 57. The method of claim 54, further comprising the
2 steps of

3 c) based on said remaining distribution function

4 $\Delta OPL(\alpha_R, \theta_R)$ of step b), determining an effective
5 birefringence distribution of a compensation coating
6 for a further reduction of the optical path differences

7 ΔOPL , wherein the compensation coating has effective

8 birefringence values dependent on azimuth angles α_F

9 measured relative to a reference direction that is

10 perpendicular to an element axis of an optical element

11 to be coated and dependent on aperture angles θ_F

12 measured relative to the element axis;

13 d) based on said effective birefringence distribution,

14 determining a design specification for the compensation

15 coating; and

16 e) applying the compensation coating to the optical

17 element of the objective.

1 58. The objective of claim 18, comprising a

2 plurality of optical elements that includes said lenses,

3 wherein the optical elements have optical surfaces and at

4 least one of said optical surfaces is coated with a
5 compensation coating, said compensation coating being
6 configured in such a way that the distribution of optical
7 path differences $\Delta OPL(\alpha_R, \theta_R)$ for a bundle of rays as a
8 function of the azimuth angle α_R and the aperture angle θ_R
9 is significantly reduced in magnitude in comparison to an
10 objective without the compensation coating.

1 59. The objective of claim 58, wherein the optical
2 element with the compensation coating has an element axis
3 and wherein the compensation coating has an effective
4 birefringence distribution with effective birefringence
5 values being a function of an azimuth angle α_F and an
6 aperture angle θ_F , said azimuth angle being measured
7 relative to a reference direction that is perpendicular to
8 the element axis and said aperture angle being measured
9 relative to the element axis.

1 60. The objective of claim 59, wherein the
2 effective birefringence value of the compensation coating
3 is approximately zero for an aperture angle of $\theta_F=0^\circ$.

1 61. The objective of claim 59, wherein the

2 effective birefringence value of the compensation coating
3 depends primarily on the aperture angle θ_F alone.

1 62. The objective of claim 58, wherein the optical
2 element with the compensation coating is one of the at
3 least two fluoride crystal lenses, and wherein the element
4 axis is the lens axis of the fluoride crystal lens with the
5 compensation coating.

1 63. The objective of claim 58, wherein more than
2 one optical element carries the compensation coating.

1 64. The objective of claim 58, wherein all of the
2 optical elements carry the compensation coatings.

1 65. An objective comprising a plurality of optical
2 elements with optical surfaces, said optical elements
3 including lenses of a fluoride crystal material with a
4 cubic lattice structure, wherein the term lenses means
5 lenses as well as lens parts, wherein an image point in an
6 image plane is formed at a convergence of a bundle of light
7 rays each of which has an optical path difference ΔOPL for
8 two mutually orthogonal states of linear polarization, and

9 wherein at least one of the optical surfaces is coated with
10 a compensation coating, said compensation coating being
11 configured in such a way that the optical path differences
12 ΔOPL that are caused by the fluoride crystal lenses are
13 significantly reduced in magnitude in comparison to an
14 objective without the compensation coating.

1 66 . The objective of claim 65, wherein the light
2 rays have wavelengths shorter than 160nm.

1 67. An objective comprising a plurality of optical
2 elements with optical surfaces, said optical elements
3 including fluoride crystal lenses, wherein the term lenses
4 means lenses as well as lens parts, wherein an image point
5 in an image plane (O') is formed at a convergence of a
6 bundle of light rays each of which has an optical path
7 difference ΔOPL for two mutually orthogonal states of
8 linear polarization, and wherein at least one of the
9 optical surfaces is coated with a compensation coating,
10 said compensation coating being configured in such a way
11 that the optical path differences ΔOPL are significantly
12 reduced in magnitude in comparison to an objective without
13 the compensation coating.

1 68. The objective of claim 67, wherein the optical
2 element with the compensation coating has an element axis
3 and wherein the compensation coating has an effective
4 birefringence distribution with effective birefringence
5 values being a function of an azimuth angle α_F and an
6 aperture angle θ_F , said azimuth angle being measured
7 relative to a reference direction that is perpendicular to
8 the element axis and said aperture angle being measured
9 relative to the element axis.

1 69. The objective of claim 68, wherein the value
2 of the effective birefringence distribution of the
3 compensation coating is approximately zero for an aperture
4 angle of $\theta_F=0^\circ$.

1 70. The objective of claim 68, wherein the
2 effective birefringence value of the compensation coating
3 depends primarily on the aperture angle θ_F alone.

1 71. The objective of claim 67, wherein the optical
2 element with the compensation coating is an interchangeable
3 element.

1 72. The objective of claim 67, wherein at least
2 two of the optical elements are fluoride crystal lenses and
3 have lens axes oriented in a principal crystallographic
4 direction or in equivalent principal crystallographic
5 directions, and wherein the lenses are arranged relative to
6 each other with a rotation relative to the lens axes in
7 such a manner that a distribution function $\Delta OPL(\alpha_R, \theta_R)$ of
8 the optical path differences of the bundle of rays as a
9 function of the azimuth angle α_R and the aperture angle θ_R
10 has significantly smaller values in comparison to lenses
11 that likewise have lens axes oriented in said principal
12 crystallographic direction or equivalent principal
13 crystallographic directions but are not arranged with said
14 rotation relative to each other.

1 73. The objective of claim 72, wherein the optical
2 path differences ΔOPL as a function of the azimuth angle α_R
3 at a fixed aperture angle θ_0 vary by less than 30% relative
4 to a maximum value of the optical path differences.

1 74. The objective of claim 72, wherein each of the
2 lenses has a birefringence distribution $\Delta n(\alpha_L, \theta_L)$ whose

3 values Δn depend on azimuth angles α_L relative to a
4 reference direction that is perpendicular to the lens axis
5 and on aperture angles θ_L relative to the lens axis, wherein
6 the birefringence distribution $\Delta n(\alpha_L, \theta_L)$ has a k-fold
7 azimuthal symmetry, wherein angles of rotation γ are defined
8 between the reference directions of the individual lenses,
9 wherein a number n of lenses form a group in which the lens
10 axes are oriented in the same or equivalent
11 crystallographic directions, and wherein in said group the
12 birefringence distributions $\Delta n(\alpha_L, \theta_L)$ relative to the
13 reference directions have the same azimuthal profiles and
14 the angle of rotation γ between two of the lenses conforms
15 to the equation $\gamma = \frac{360^\circ}{k \cdot n} + m \cdot \frac{360^\circ}{k} \pm 10^\circ$ with m representing an
16 integer.

1 75. The objective of claim 72, wherein each of the
2 lenses has a birefringence distribution $\Delta n(\alpha_L, \theta_L)$ whose
3 values Δn depend on aperture angles θ_L relative to the lens
4 axes and on azimuth angles α_L relative to a reference
5 direction that is perpendicular to the lens axis, wherein
6 the birefringence distribution $\Delta n(\alpha_L, \theta_L)$ has a k-fold

7 azimuthal symmetry, wherein angles of rotation γ are defined
8 between the reference directions of the individual lenses,
9 wherein a number n of subgroups of lenses form a group in
10 which the lens axes are oriented in the same or equivalent
11 crystallographic directions, and wherein in said group the
12 birefringence distributions $\Delta n(\alpha_L, \theta_L)$ relative to the
13 reference directions have the same azimuthal profiles,
14 wherein each of the n subgroups comprises at least one
15 lens, wherein the angle of rotation γ between any two of the
16 lenses within one of the subgroups conforms to the equation

$$17 \gamma = l \cdot \frac{360^\circ}{k} \pm 10^\circ \text{ and the angle of rotation } \gamma \text{ between two lenses}$$

18 from different subgroups conforms to the equation

$$19 \gamma = \frac{360^\circ}{k \cdot n} + m \cdot \frac{360^\circ}{k} \pm 10^\circ \text{ with } l \text{ and } m \text{ representing integer}$$

20 numbers.

1 76. The objective of claim 72, wherein the optical
2 element with the compensation coating is one of the
3 fluoride crystal lenses, and wherein the element axis is
4 the lens axis of the fluoride crystal lens.

1 77. The objective of claim 67, wherein more than
2 one optical element is coated with a compensation coating.

1 78. The objective of claim 67, wherein the
2 objective conforms to at least one of the criteria that:
3 - the objective has a numerical aperture NA larger than
4 0.7 on the image side,
5 - the objective has a numerical aperture NA larger than
6 0.8 on the image side,
7 - the objective is designed to operate with wavelengths
8 shorter than 200 nanometers,
9 - the objective is designed to operate with wavelengths
10 shorter than 160 nanometers,
11 - the objective is a refractive objective,
12 - the objective is a catadioptric objective with lenses
13 and at least one mirror, and
14 - all lenses of the objective consist of calcium fluoride.

1 79. A microlithography projection system,
2 comprising an illumination system and further comprising
3 the objective of claim 67, wherein the objective projects
4 an image of a mask carrying a structure onto a light-
5 sensitive substrate.

1 80. A method of manufacturing semiconductor

2 components comprising a step in which the microlithography
3 projection system of claim 79 is used.

1 81. A method of compensating effects caused by
2 birefringence in an objective that has a plurality of
3 optical elements with optical surfaces, including fluoride
4 crystal lenses, wherein at least one of said optical
5 elements is an interchangeable element, wherein an image
6 point in an image plane is formed at a convergence of a
7 bundle of light rays, each of said rays having an azimuth
8 angle α_R , an aperture angle θ_R and an optical path
9 difference ΔOPL for two mutually orthogonal states of
10 linear polarization, and wherein said method comprises the
11 steps of
12 a) determining a distribution of optical path differences
13 $\Delta OPL(\alpha_R, \theta_R)$;
14 b) based on said distribution $\Delta OPL(\alpha_R, \theta_R)$, determining an
15 effective birefringence distribution of a compensation
16 coating to be applied to the interchangeable element,
17 wherein the compensation coating has effective
18 birefringence values dependent on azimuth angles α_F
19 measured relative to a reference direction that is
20 perpendicular to an element axis of the optical element

21 and dependent on aperture angles θ_F measured relative to
22 the element axis;

23 c) taking the optical element out of the objective;

24 d) applying the compensation coating to the
25 interchangeable element; and

26 e) reinstalling the optical element in the objective.

1 82. An objective comprising at least two lenses
2 consisting of fluoride crystal material, wherein the term
3 lenses means lenses as well as lens parts, wherein said
4 lenses have lens axes oriented substantially in a principal
5 crystallographic direction, wherein an image point in an
6 image plane is formed at a convergence of a bundle of light
7 rays each of which has an azimuth angle α_R , an aperture
8 angle θ_R and an optical path difference ΔOPL for two
9 mutually orthogonal states of linear polarization, wherein
10 the lenses are arranged with a rotation relative to each
11 other about the lens axes in such a manner that a
12 distribution $\Delta OPL(\alpha_R, \theta_R)$ of the optical path differences as
13 a function of the azimuth angle α_R and the aperture angle
14 θ_R has significantly reduced values of ΔOPL in comparison to
15 an arrangement where said lenses are likewise oriented in
16 said principal crystallographic direction but are not

18 arranged with said rotation relative to each other, wherein
19 said objective comprises a composite lens in which a
20 plurality of plates consisting of crystal material are
21 seamlessly joined together, said plates being
22 crystallographically oriented at mutually rotated positions
23 relative to a normal axis of each plate.

1 83. An objective comprising a plurality of optical
2 elements with optical surfaces, said optical elements
3 including fluoride crystal lenses, wherein the term lenses
4 means lenses as well as lens parts, wherein an image point
5 in an image plane is formed at a convergence of a bundle of
6 light rays each of which has an optical path difference
7 ΔOPL for two mutually orthogonal states of linear
8 polarization, and wherein at least one of the optical
9 surfaces is coated with a compensation coating, said
10 compensation coating being configured in such a way that
11 the optical path differences ΔOPL are significantly reduced
12 in magnitude in comparison to an objective without the
13 compensation coating, wherein said objective comprises a
14 composite lens in which a plurality of plates consisting of
15 crystal material are seamlessly joined together, said
16 plates being crystallographically oriented at mutually
17 rotated positions relative to a normal axis of each plate.